PATENT APPLICATION

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re the Application of

Yoshitaka SASAKI

Application No.: Rule 53(b) Divisional Application of
U.S. Patent Application No. 09/328,415

Filed: December 6, 2001 Docket No.: 103551.01

For: THIN FILM MAGNETIC HEAD AND METHOD OF MANUFACTURING THE SAME

PRELIMINARY AMENDMENT

Director of the U.S. Patent and Trademark Office
Washington, D. C. 20231

Sir:

Prior to initial examination, please amend the above-identified application as follows:

IN THE ABSTRACT:

Please replace the Abstract filed with the attached Abstract hereto.

IN THE SPECIFICATION:

Page 3, lines 22 - page 6, line 22, delete current paragraphs and insert therefor:

Here, an example of a method of manufacturing a composite thin film magnetic head will be described with reference to FIGs. 17A, 17B to FIGs. 22A, 22B as an example of a method of manufacturing a thin film magnetic head of the related art.

As shown in FIG. 17, an insulating layer 102 made of , for example, alumina (aluminum oxide, Al_2O_3) is formed to a thickness of about 5 to 10 μm on a substrate of 101 made of, for example, aluminum oxide and titanium carbide (Al_2O_3 TiC). Further, a bottom

shield layer 103 for a reproducing head made of, for example, permalloy (NiFe) is formed on the insulating layer 102.

Next, as shown in FIG. 18, for example, alumina of about 100-200 nm in thickness is deposited on the bottom shield layer 103 to form a shield gap film 104. Next, an MR film 105 of tens of nanometers in thickness for making up the MR element for reproducing is formed on the shield gap film 104, and photolithography with high precision is applied to obtain a desired shape. Next, a lead terminal layer 106 for the MR film 105 is formed by lift-off method. Next, a shield gap film 107 is formed on the shield gap film 104, the MR film 105 and the lead terminal layer 106, and the MR film 105 and the lead terminal layer 106 are buried in the shield gap films 104 and 107. Next, a top shield-cum-bottom pole (called bottom pole in the followings) 108 of about 3 μm in thickness made of, for example, permalloy (NiFe), which is a material used for both of the reproducing head and the recording head, is formed on the shield gap film 107.

Next, as show in FIG. 19, a write gap layer 109 of about 200 nm in thickness made of an insulating layer such as an alumina film is formed on the bottom pole 108. Further, an opening 109a for connecting the top pole and the bottom pole is formed through patterning the write gap layer 109 by photolithography. Next, a pole tip 110 is formed with magnetic materials made of permalloy (NiFe) and nitride ferrous (FeN) through plating method, while a connecting-portion pattern 110a of the top pole and the bottom pole is formed. The bottom pole 108 and a top pole layer 116 which is to be described later are connected by the connecting-portion pattern 110a and so that forming a through hole after CMP (Chemical and Mechanical Polishing) procedure, which is to be described later, becomes easier.

Next, as shown in FIG. 20, the write gap layer 109 and the bottom pole 108 are etched about 0.3-0.5 μm by ion milling with the pole tip 110 being a mask. By etching the bottom pole 108 to be a trim structure, widening of effective write track width can be avoided (that

is, suppressing spread of magnetic flux in the bottom pole when data is being written). Next, after an insulating layer 111 of about 3 μm made of, for example, alumina is formed all over the surface, the whole surface is flattened by CMP.

Next, as shown in FIG. 21 a first layer of thin film coil 112 for an inductive-type recording head made of, for example, copper (Cu) is selectively formed on the insulating layer 111 by, for example, plating method. Further, a photoresist film 113 is formed in a desired pattern on the insulating layer 111 and the thin film coil 112 by photolithography with high precision. Further, a heat treatment of desired temperature is applied to flatten the photoresist film 113 and to insulate between the turns of the thin film coil 112. Likewise, a second layer of thin film coil 114 and a photoresist film 115 are formed on the photoresist film 113, and a heat treatment of desired temperature is applied to flatten the photoresist film 115 and to insulate between the turns of the thin film coils 114.

Next, as shown in FIG. 22, a top yoke-cum-top pole layer (called a top pole layer in the followings) 116 made of, for example, permalloy, which is a magnetic material for recording heads, is formed on the top pole 110, the photoresist films 113 and 115. The top pole layer 116 is in contact with the bottom pole 108 in a position recessed from the thin film coils 112 and 114, while being magnetically coupled to the bottom pole 108. Further, an over coat layer 117 made of, for example, alumina is formed on the top pole layer 116. At last, a track surface (air bearing surface) of the recording head and the reproducing head is formed through performing machine processing on the slider to complete a thin film magnetic head.

In FIG. 22, TH represents the through height and MR-H represents the MR height. Further, P2W represents the track (magnetic pole) width.

As an factor for determining the performance of a thin film magnetic head, there is an apex angle as represent by θ in FIG. 22 besides the throat height TH and the MR height MR-H and so on. The apex angle is an angle between a line connecting the corner of a side

surface of the track surface of the photoresist films 113, 115 and an upper surface of the top pole layer 116.

To improve the performance of a thin film magnetic head, it is important to precisely form the throat height TH, the MR height MR-H and the apex angle θ as shown in FIG. 22.

Page 7, lines 8-11, delete current paragraph and insert therefor:

Here, the problem is that it is difficult to minutely form the top pole layer 116 on a coil portion (apex area) which is protruded like a mountain covered with photoresist films (for example, the photoresist films 113 and 115 in FIG. 22).

Page 8, lines 13 - page 9, line 1, delete current paragraph and insert therefor:

For the reasons described above, as shown in the procedure of an example of the related art in FIG. 19 to FIG. 22, a method of connecting the pole tip 110 and a yoke area-cum-top pole layer 116 after forming a track width of 1.0 μm or less with the pole tip 110 which is effective for forming a narrow track of a recording head, that is, a method of dividing the regular top pole into the pole tip 110 for determining the track width and the top pole layer 116 which becomes the yoke for inducing magnetic flux is employed (Ref. Japanese Patent Application laid-open Sho 62-245509, Sho 60-10409). By dividing the top pole into two as described, the pole tip 110 can be minutely processed to submicron width on a flat surface of the write gap layer 109. The track width of the recording head is determined by the pole tip 110 so that the other top pole layer 116 is not required to be minutely processed comparing to the pole tip 110.

Page 16, before line 23, insert therefor:

FIGs. 16A and 16B are cross sections showing the configuration of a thin film magnetic head according to another embodiment of the invention.

Page 16, lines 23 - page 17, line 10, delete current paragraphs and insert therefor:

FIGs. 17A and 17B are cross sections for describing a method of manufacturing a thin film magnetic head of the relating art.

FIGs. 18A and 18B are cross sections for describing the following procedure shown in FIGs. 17A and 17B.

FIGs. 19A and 19B are cross sections for describing the following procedure shown in FIGs. 18A and 18B.

FIGs. 20A and 20B are cross sections for describing the following procedure shown in FIGs. 19A and 19B.

FIGs. 21A and 21B are cross sections for describing the following procedure shown in FIGs. 20A and 20B.

FIGs. 22B and 22B are cross sections for describing the following procedure shown in FIGs. 21A and 21B.

Page 29, lines 1-7, delete current paragraph and insert therefor:

In the embodiment with such a configuration, a taper surface 28a is formed on the insulating layer 21a on both sides of the pole tip 20, and the pole tip 20 and the top pole layer 25c are not in contact vertically. As a result, saturation of magnetic flux in the area does not occur so that flux rise time becomes shorter and side-writing is prevented from occurring. Accordingly, writing performance is improved. Other effects of the embodiment is similar to those of the first embodiment.

Page 30, lines 5-12, delete current paragraph and insert therefor:

Further, the second magnetic layer (top pole layer 25c) is not necessarily required to be exposed on the side of the medium-facing-surface (air bearing surface). For example, in the embodiment shown in FIG. 16A, the second magnetic layer 25c is not in contact with the whole surface of the pole tip, but is in contact with the surface of the pole tip in a position

recessed away from the medium-facing-surface. In such a case, the second magnetic layer can be coated by an over coat layer so that it is not exposed onto the medium-facing-surface.

<u>IN THE CLAIMS</u>:

Please cancel claims 1-25 without prejudice to or disclaimer of the subject matter contained therein.

Please add new claims 26-31 as follows:

--26. (New) A method of manufacturing a thin film magnetic head having at least two magnetic layers including at least a first magnetic pole and a second magnetic pole magnetically coupled to each other while part of sides facing a recording medium face each other with a write gap layer in between, and at least one layer of thin film coil for generating magnetic flux, the method comprising the steps of:

forming a first magnetic layer including the first magnetic pole;

selectively forming a pole tip at least over the first magnetic pole of the first magnetic layer with the write gap layer in between the pole tip and the first magnetic layer, the pole tip serving as the second magnetic pole;

forming a first insulating layer extending at least from surfaces of the pole tip and the write gap layer which are opposite a side facing the recording medium to a top surface of the first magnetic layer;

forming the at least one layer of thin film coil over at least a portion of the first insulating layer;

forming a second insulating layer so as to entirely cover top surfaces of the pole tip and the at least one layer of thin film coil;

planarizing a top surface of the second insulating layer to be substantially level with the top surface of the pole tip;

selectively etching part of the top surface of the pole tip so as to become lower than an edge surface of the first insulating layer which is formed on a side wall of the pole tip and to form a tapered portion in the edge surface of the first insulating layer; and

forming a second magnetic layer over the pole tip and the second insulating layer, the second magnetic layer connected to the top surface of the pole tip through the tapered portion of the first insulating layer.--

--27. (New) A method of manufacturing a thin film magnetic head according to claim 26, wherein the step of selectively etching part of the top surface of the pole tip is performed by means of ion milling.--

--28. (New) A method of manufacturing a thin film magnetic head according to claim 26, wherein the first insulating layer is formed with an inorganic insulating material.--

--29. (New) A method of manufacturing a thin film magnetic head according to claim 26, wherein,

the write gap layer is formed on the entire top surface of the first magnetic layer, the step of selectively forming the pole tip includes selectively forming the pole tip on the write gap layer, and the method further comprises forming a concave area on the first magnetic layer by selectively etching the top surfaces of the write gap layer and the first magnetic layer using the pole tip as a mask.--

--30. (New) A method of manufacturing a thin film magnetic head according to claim 29, wherein the write gap layer is etched using the pole tip as a mask in order for part of the write gap layer to remain.--

--31. (New) A method of manufacturing a thin film magnetic head according to claim 26, wherein a surface of the second magnetic layer facing the recording medium is recessed from a surface of the pole tip facing the recording medium.--

REMARKS

Claims 26-31 are pending. By this Amendment, the abstract and the specification are amended, claims 1-25 are cancelled, and claims 26-31 are added.

This application is placed in condition for initial examination. Prompt examination and allowance in due course are respectfully solicited.

Respectfully submitted,

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JAO:BMH/gpn

Attachments:
Abstract
Appendix

Date: December 6, 2001

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DEPOSIT ACCOUNT USE
AUTHORIZATION
Please grant any extension
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ABSTRACT

A method of manufacturing a thin film magnetic head in which a top pole is divided into a pole tip and a tope pole layer, and the pole tip is formed on the flat surface of a bottom pole with a write gap layer in between. An insulating layer is formed in a region adjacent to the pole tip. A first layer of thin film coil is formed in a region wherein the insulating layer is formed. The thin film coil is covered by the insulating layer whose surface is flattened. A surface of the top pole layer facing the recording medium can be formed recessed from a surface of the pole tip facing the recording medium.

APPENDIX

Changes to Specification:

Page 3, lines 22 - page 6, line 22:

Here, an example of a method of manufacturing a composite thin film magnetic head will be described with reference to FIGs. ~~16A, 16B to FIGs. 21A, 21B~~ 17A, 17B to FIGs. 22A, 22B as an example of a method of manufacturing a thin film magnetic head of the related art.

As shown in FIG. ~~16~~17, an insulating layer 102 made of , for example, alumina (aluminum oxide, Al_2O_3) is formed to a thickness of about 5 to 10 μm on a substrate of 101 made of, for example, aluminum oxide and titanium carbide (Al_2O_3 TiC). Further, a bottom shield layer 103 for a reproducing head made of, for example, permalloy (NiFe) is formed on the insulating layer 102.

Next, as shown in FIG. ~~17~~18, for example, alumina of about 100-200 nm in thickness is deposited on the bottom shield layer 103 to form a shield gap film 104. Next, an MR film 105 of tens of nanometers in thickness for making up the MR element for reproducing is formed on the shield gap film 104, and photolithography with high precision is applied to obtain a desired shape. Next, a lead terminal layer 106 for the MR film 105 is formed by lift-off method. Next, a shield gap film 107 is formed on the shield gap film 104, the MR film 105 and the lead terminal layer 106, and the MR film 105 and the lead terminal layer 106 are buried in the shield gap films 104 and 107. Next, a top shield-cum-bottom pole (called bottom pole in the followings) 108 of about 3 μm in thickness made of, for example, permalloy (NiFe), which is a material used for both of the reproducing head and the recording head, is formed on the shield gap film 107.

Next, as show in FIG. ~~18~~19, a write gap layer 109 of about 200 nm in thickness made of an insulating layer such as an alumina film is formed on the bottom pole 108. Further, an opening 109a for connecting the top pole and the bottom pole is formed through patterning the write gap layer 109 by photolithography. Next, a pole tip 110 is formed with magnetic materials made of permalloy (NiFe) and nitride ferrous (FeN) through plating method, while a connecting-portion pattern 110a of the top pole and the bottom pole is formed. The bottom pole 108 and a top pole layer 116 which is to be described later are connected by the connecting-portion pattern 110a and so that forming a through hole after CMP (Chemical and Mechanical Polishing) procedure, which is to be described later, becomes easier.

Next, as shown in FIG. ~~19~~20, the write gap layer 109 and the bottom pole 108 are etched about 0.3-0.5 μm by ion milling with the pole tip 110 being a mask. By etching the bottom pole 108 to be a trim structure, widening of effective write track width can be avoided (that is, suppressing spread of magnetic flux in the bottom pole when data is being written). Next, after an insulating layer 111 of about 3 μm made of, for example, alumina is formed all over the surface, the whole surface is flattened by CMP.

Next, as shown in FIG. ~~20~~ 21 a first layer of thin film coil 112 for an inductive-type recording head made of, for example, copper (Cu) is selectively formed on the insulating layer 111 by, for example, plating method. Further, a photoresist film 113 is formed in a desired pattern on the insulating layer 111 and the thin film coil 112 by photolithography with high precision. Further, a heat treatment of desired temperature is applied to flatten the photoresist film 113 and to insulate between the turns of the thin film coil 112. Likewise, a second layer of thin film coil 114 and a photoresist film 115 are formed on the photoresist film 113, and a heat treatment of desired temperature is applied to flatten the photoresist film 115 and to insulate between the turns of the thin film coils 114.

Next, as shown in FIG. ~~21~~22, a top yoke-cum-top pole layer (called a top pole layer in the followings) 116 made of, for example, permalloy, which is a magnetic material for recording heads, is formed on the top pole 110, the photoresist films 113 and 115. The top pole layer 116 is in contact with the bottom pole 108 in a position recessed from the thin film coils 112 and 114, while being magnetically coupled to the bottom pole 108. Further, an over coat layer 117 made of, for example, alumina is formed on the top pole layer 116. At last, a track surface (air bearing surface) of the recording head and the reproducing head is formed through performing machine processing on the slider to complete a thin film magnetic head.

In FIG. ~~21~~22, TH represents the through height and MR-H represents the MR height. Further, P2W represents the track (magnetic pole) width.

As an factor for determining the performance of a thin film magnetic head, there is an apex angle as represent by θ in FIG. ~~21~~ 22 besides the throat height TH and the MR height MR-H and so on. The apex angle is an angle between a line connecting the corner of a side surface of the track surface of the photoresist films 113, 115 and an upper surface of the top pole layer 116.

To improve the performance of a thin film magnetic head, it is important to precisely form the throat height TH, the MR height MR-H and the apex angle θ as shown in FIG. ~~21~~22.

Page 7, lines 8-11:

Here, the problem is that it is difficult to minutely form the top pole layer 116 on a coil portion (apex area) which is protruded like a mountain covered with photoresist films (for example, the photoresist films 113 and 115 in FIG. ~~21~~22).

Page 8, lines 13 - page 9, line 1:

For the reasons described above, as shown in the procedure of an example of the related art in FIG. ~~18~~ 19 to FIG. ~~21~~22, a method of connecting the pole tip 110 and a yoke area-cum-top pole layer 116 after forming a track width of 1.0 μm or less with the pole tip 110 which is effective for forming a narrow track of a recording head, that is, a method of dividing the regular top pole into the pole tip 110 for determining the track width and the top pole layer 116 which becomes the yoke for inducing magnetic flux is employed (Ref. Japanese Patent Application laid-open Sho 62-245509, Sho 60-10409). By dividing the top pole into two as described, the pole tip 110 can be minutely processed to submicron width on a flat surface of the write gap layer 109. The track width of the recording head is determined by the pole tip 110 so that the other top pole layer 116 is not required to be minutely processed comparing to the pole tip 110.

Page 16, before line 23 insert:

FIGs. 16A and 16B are cross sections showing the configuration of a thin film magnetic head according to another embodiment of the invention.

Page 16, lines 23 - page 17, line 10:

FIGs. ~~16A~~ 17A and ~~16B~~ 17B are cross sections for describing a method of manufacturing a thin film magnetic head of the relating art.

FIGs. ~~17A~~ 18A and ~~17B~~ 18B are cross sections for describing the following procedure shown in FIGs. ~~16A~~ 17A and ~~16B~~17B.

FIGs. ~~18A~~ 19A and ~~18B~~ 19B are cross sections for describing the following procedure shown in FIGs. ~~17A~~ 18A and ~~17B~~18B.

FIGs. ~~19A~~ 20A and ~~19B~~ 20B are cross sections for describing the following procedure shown in FIGs. ~~18A~~ 19A and ~~18B~~19B.

FIGs. ~~20A~~ 21A and ~~20B~~ 21B are cross sections for describing the following procedure shown in FIGs. ~~19A~~ 20A and ~~19B~~20B.

FIGs. ~~21A~~ 22B and ~~21B~~ 22B are cross sections for describing the following procedure shown in FIGs. ~~20A~~ 21A and ~~20B~~21B.

Page 29, lines 1-7:

In the embodiment with such a configuration, a taper surface ~~26a~~ 28a is formed on the insulating layer 21a on both sides of the pole tip 20, and the pole tip 20 and the top pole layer 25c are not in contact vertically. As a result, saturation of magnetic flux in the area does not occur so that flux rise time becomes shorter and side-writing is prevented from occurring. Accordingly, writing performance is improved. Other effects of the embodiment is similar to those of the first embodiment.

Page 30, lines 5-12:

Further, the second magnetic layer (top pole layer 25c) is not necessarily required to be exposed on the side of the medium-facing-surface (air bearing surface). ~~That means~~For example, in the embodiment shown in FIG. 16A, the second magnetic layer 25c is not ~~required to be~~ in contact with the whole surface of the pole tip, but ~~may be~~is in contact with the surface of the pole tip in a position ~~recessed to inner side (for example, right-hand side in FIG. 9)~~away from the medium-facing-surface. In such a case, the second magnetic layer ~~is~~ can be coated by an over coat layer so that it is not exposed onto the medium-facing-surface.

Changes to Claims:

Claims 1-25 are canceled.

Claims 26-31 are added.

26. (New) A method of manufacturing a thin film magnetic head having at least two magnetic layers including at least a first magnetic pole and a second magnetic pole magnetically coupled to each other while part of sides facing a recording medium face each other with a write gap layer in between, and at least one layer of thin film coil for generating magnetic flux, the method comprising the steps of:

forming a first magnetic layer including the first magnetic pole;

selectively forming a pole tip at least over the first magnetic pole of the first magnetic layer with the write gap layer in between the pole tip and the first magnetic layer, the pole tip serving as the second magnetic pole;

forming a first insulating layer extending at least from surfaces of the pole tip and the write gap layer which are opposite a side facing the recording medium to a top surface of the first magnetic layer;

forming the at least one layer of thin film coil over at least a portion of the first insulating layer;

forming a second insulating layer so as to entirely cover top surfaces of the pole tip and the at least one layer of thin film coil;

planarizing a top surface of the second insulating layer to be substantially level with the top surface of the pole tip;

selectively etching part of the top surface of the pole tip so as to become lower than an edge surface of the first insulating layer which is formed on a side wall of the pole tip and to form a tapered portion in the edge surface of the first insulating layer; and

forming a second magnetic layer over the pole tip and the second insulating layer, the second magnetic layer connected to the top surface of the pole tip through the tapered portion of the first insulating layer.

27. (New) A method of manufacturing a thin film magnetic head according to claim 26, wherein the step of selectively etching part of the top surface of the pole tip is performed by means of ion milling.

28. (New) A method of manufacturing a thin film magnetic head according to claim 26, wherein the first insulating layer is formed with an inorganic insulating material.

29. (New) A method of manufacturing a thin film magnetic head according to claim 26, wherein,

the write gap layer is formed on the entire top surface of the first magnetic layer, the step of selectively forming the pole tip includes selectively forming the pole tip on the write gap layer, and the method further comprises forming a concave area on the first magnetic layer by selectively etching the top surfaces of the write gap layer and the first magnetic layer using the pole tip as a mask.

30. (New) A method of manufacturing a thin film magnetic head according to claim 29, wherein the write gap layer is etched using the pole tip as a mask in order for part of the write gap layer to remain.

31. (New) A method of manufacturing a thin film magnetic head according to claim 26, wherein a surface of the second magnetic layer facing the recording medium is recessed from a surface of the pole tip facing the recording medium.